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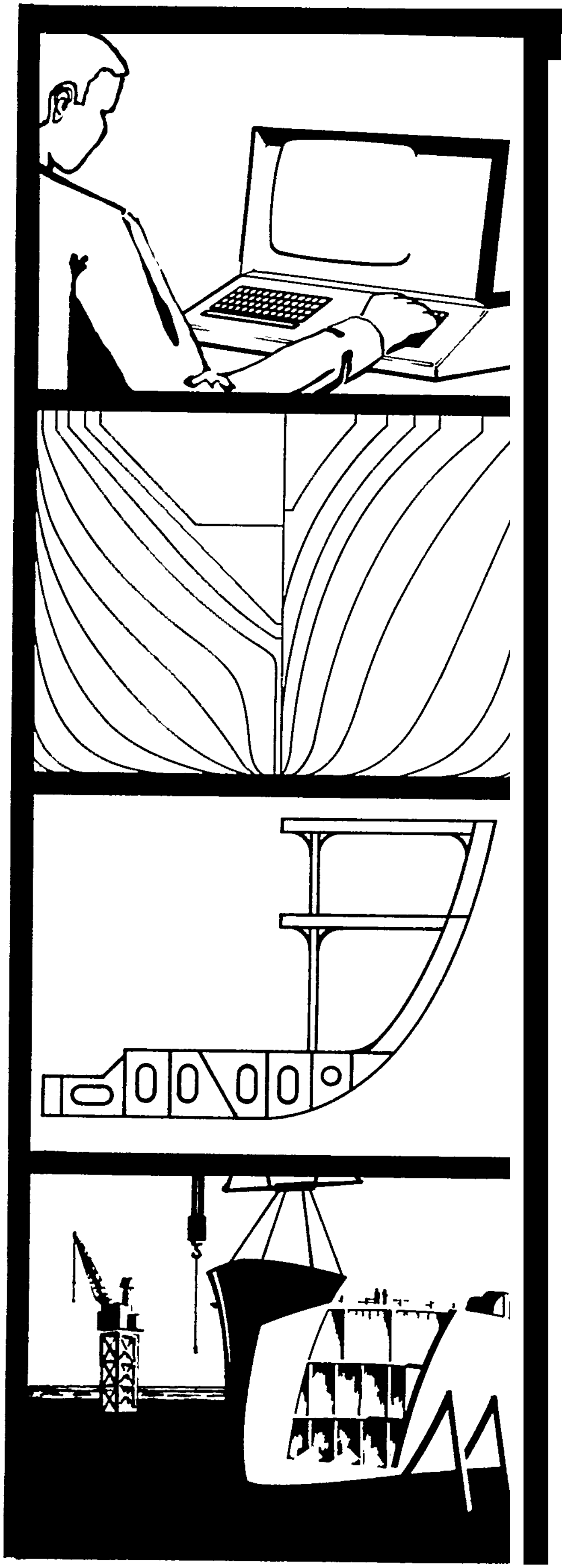

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REDUCING PRODUCTION MAN-HOURS
THROUGH DESIGN OFFICE PROCEDURES
STRUCTURAL DESIGNER-FABRICATOR RELATIONSHIP

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REDUCING PRODUCTION MANHOURS THROUGH DESIGN OFFICE PROCEDURES STRUCTURAL DESIGNER FABRICATOR RELATIONSHIP

Abstract: The shipyards in this country have spent a sizable amount of money to modernize their methods of fabrication to increase construction. The shipbuilding industry is a labor hitensive business based on small orders of ships that does not allow for total automation in the near term, if ever. One area of a shipyard that has minor or limited changes is the structural design office. The manual drafting of working drawings is basically the same as the methods used in the 1950's. A number of yards have restructured the working drawing to assembly type drawings. This is a major change assisting in the construction of the ship, but is still limited in scope. The present method does not allow for an orderly progression into the application of computers. The development of working drawings to assist construction is-poor and this stagnation has restricted the design. office from converting drawings to computers.

The problem stems from false economy values. The idea that a limited budget for the development of working drawings will increase the yard's profit margin is a false one. Every effort, or person hour, used in design should have a direct savings in production manhours. The goal of the designer's output should be a necessary and direct part of the construction program. Many design offices may not even realize that they are not truly reducing costs, but are driving them up due to poor dettailing. (A complete study of the working drawing process should be made objectively by design, production and planning people). This paper may give the basic outlines for consideration. Thomas P. Gallagher, Surface Ship Structures, Head, Research, Dynamic/Highedr Performance Craft Section, Phone 202-692-9107, Naval Ship Engineering Center.

DESIGNER – FABRICATOR RELATIONSHIP

Introduction - Over the past five years, the author has had the opportunity to participate in the development and implementation of a special computer system. It had, as its goal, the reduction of shipbuilding costs through automation of the design, detailing and fabrication process. During this time some observations and conclusions have been developed concerning the interrelationship of the design offices and the building yard and how the present process and attitudes must be changed if we are to realize the full potential of modern technology available through the computer and numerically controlled equipment. It is hoped that the thoughts expressed in this paper will be perceived as an overview of one who can understand the reluctance of men to change, despite the necessity to do so, and not as a criticism of an industry that has performed so well over the years.

Where to begin - The traditional design process requires that upon completion of a design, competitive bids are received and a contract let to build the ship. The yard winning the competition will require an in-house engineering staff, a design agent, or both, to develop the working drawings. He will require a production department to plan construction and shops to do the myriad of jobs required to finally develop a constmcted ship. To be most effective the working drawings should be developed with production in mind.

To be most effective, production should be kept in mind when the working drawings are being developed.

Shipbuilding today is still a construction rather than a production industry. This equates to the difference between house construction as to automobile production. If automobiles were constructed, instead of produced, we would pay a minimum of 3 to 5 times the cost with more problems than we have today. Shipbuilding is a labor intensive industry which has a high cash flow that should require a positive change to production instead of the stick by stick construction so familiar today.

Shipyards have made many changes in their method of construction, but, in most cases, have not carried the changes back up stream to include the engineering or design process. The need to convert more shipbuilding to production, rather than construction, is a major way of reducing costs. The advancement of ship construction methods must be reflected back into the working drawing and contact design process. The time and money this could save, even with manual drafting methods, when properly managed, would be of a major magnitude. A design agent may find this more difficult than a yard with inhouse design services, but the difficulties could be minimized with a proper interface. The design agent may require ,different drawings for different yards building the same ships to suit their special practice. Under a manual method most detailed information could be copied or traced, while with a computer database, a modification to general assembly instructions would be required.

Today, some yards have assembly type drawings while others have stayed with their conventional systems. The conventional method of working drawing development is basically for the ease of the designer and not the need of the shipbuilder. This may take time to realize but let us consider the problem using conventional methods: how rnany drawings is a deck made up of and why. Generally, it is based on the length of ship and the scale of the drawing. Design offices have been known to use drawings 12 feet or less because of the Iengh of drawing boards, or because of the reproduction process. In some yards the answer may be that we have held to this size since the war. One reason for lack of progress in the design area, is the shipyards allow the design office to develop the drawings to suit themselves. Most shipyards realize this. They have systems to compensate for the situation, such as the use of revision or modification notices, and shop sketches to update and breakdown the working drawings. In reality it is to work around the poor practice in a design office. Part of the problem is design and production are under different heads. They may have equal status in the organization but this does not allow the production head to require a change in design process to suit inhouse production. On designs with a design agent the problem is money, based on the least cost of detail drawings.

Restructure of a shipyards design and construction methods could be accomplished by establishing new ground rules. When a new ship contract is awarded for a certain class of ship, the design office must prepare a schedule of working drawings. Under Navy specifications this list is required 120 days from award. Prior to award, shipyards do not review the contract package in detail to finalize a construction schedule, or more important, the method of construction. This is the first problem that starts the wheels of progress turning in different directions. The shipyard planning office is dividing the ship up for a possible construction schedule required 150 days from award while the design office is dividing the hull to suit a design schedule, Without proper interface, no change in the working drawing process will be made. One solution to this problem would be a change in the Navy requirements. This change would allow for the drawing schedule to slip from 30 to 60 days after the fabrication and erection schedule, and early drawing schedules would establish guidelines not firm milestones.

This would open up a new avenue that would enhance the overall construction process. The drawings would truly reflect the method of construction. A step further would be to. divide the ship in the area of transverse bulkheads. The various compartments would become assemblies, and from then on the ship would always be treated as an assembly. The first or second transverse bulkheads forward would be Assembly #1, the next one, or two, transverse bulkheads would make up Assembly.#2, and the machinery spaces would be a complete assembly. The superstructure could be one (1) or two (2) assemblies, based on complexity, Some shipyards build the superstructure early, as it is quick to erect. This gives them added storage area during construction when storage, not land, is a problem.

A simple layout of the shell and decks would be required to run the longitudinal members and plate seams. The contract drawing or modification of them could be used for this purpose. This could then be subdivided in accordance with the assembly approach.

A small profile drawing with as assembly areas noted and approximate frames are given to insure everyone works and understands that assembly. This is not a new idea as it was used on Victory ships to help new People to become familiar with the output of the ship. This is a simple tool that is a great help. See Figure 1.

This method of drawing development has done many things. First, with limited manpower two (2) or three (3) designers can develop an assembly. When an area of the ship is complex, structurally, the assembly should be a smaller area. Where an assembly is generally habitability, machinery, electronics, or missile spaces, the only structural drawing required would be available as a package. See Figure 2. The different surfaces would be the main and 2nd deck Assembly #2; port shell Assembly #2, starboard shell Assembly #2; and transverse bulkheads Assembly #2. This now allows changing piece marking method to comply with the new assembly approach. All of **Assembly #I** would have 1,000 numbers, Aisembly #2 would have 2,000 numbers. In most hulls this would be a viable system and would help control the job by using lots in the fabrication shops. The next breakdown would be by surface, such as deck shell, web frames and miscellaneous structures with the second number indicating this level. All the pieces on the deck could be 1100 to 1299, and 1300 to 1399 for the stiffeners on the starboard shell, with the next hundred piece numbers being the port shell. Another positive feature is the resulting standardization of the piece numbers from assembly to assembly. Care should be taken when assigning piece numbers, as each insignificant piece number would add costs to an assembly. The piece numbers should be based on a family of parts not a separate identification.

A number of advantages have been gained, as follows:

1. We have utilized the hull in the same manner as the ship is laid out and constructed. Associated systems have complete packages to run their services. The drawings reflect the erection schedule and will allow for an earlier start up.

2. We have restricted, or limited, the concern for the designers. This alone is of utmost importance because an assembly leader, or senior designer, could be assigned the responsibility of one or more assemblies, assisted by junior men in the actual development.

Revisions on structural drawings are usually done because of associated drawings. Having invoked the assembly method, all associated structured drawings are in the same assembly package. One revision covers the deck, shell, bulkheads, web frame and miscellaneous bulkheads. In an extreme case let us assume a change affected all of these surfaces. The conventional approach would require design groups, and production people, to wait for five dfiferent drawing revisions to complete a cycle. In some yards, the deck drawings are only issued a limited number of times because of the cost of reproduction. With the assembly method, all groups would have a single point of contact to check with the senior designer, that is their assembly leader. In expanding shipyards, this information could be posted, thereby directing employees to the right source.

From the management end, the assembly method would allow a greater control of manpower. Many of the assemblies would be of a similar size and complexity :therefore, measurement of the man could be made based on performance. The possibility of compatibility would markedly increase because all associated plated surfaces would be developed together. Proper development of the bulkheads and platforms would be simplified because the deck and shell associates are within reach all the time. The entire yard will talk in terms of assemblies, not parts. This would reduce the mess that results from hundreds of drawings.

With the suggested change in the design office, the people involved should find they like the small drawing packages. This will allow a great control of associated systems as the structural drawing would indicate major and minor holes in the shell, deck, and bulkhead. It is said that the first step is the hardest. Now that we are on our way, let us consider the reason for development of the drawings, and have the requirements changed.

Looking back over the previous method of assemblies, there was no mention of details. This is very important to insure standardization. The design of details must be controlled, a special detailed drawing developed, and all reference to details will be made on on the assembly drawing, but the detail will only appear in the standard detail book. This should also include the welding requirements for most fillet welds. A great deal of time and money is spent on the repetition of details in a design. Look at all the bulkhead drawings for any ship. The number of repeat details make summer television look good: By using this, we are eliminating personal preference, as the designers were generally trained at different shipyards, and this is a reason for the detailing difference. A supervisor has only to check the detailing booklet and he will know if all assemblies are being detailed in the same manner. This may take a little pride of authorship away, but the competition of the assembly approach should offset this concern. Think about adding estimated manhours for installation, or weight factors to all details, so the designer, when selecting one, will pick the more economical type for the service intended.

We can now see that the drawings are becoming more compact, simple, and easily read, but for whom are we developing the drawings?

In the past, with the large deck and shell drawings, and most pieces being fabricated on the building ways, the conventional drawing practice was adequate. With photo lofting, the method may have merit, but with the use of numerical control burning equipment it is a whole new ball game. Most design offices do not play the game. The numerical control burning equipment should be as important to the designer as to the shipfitter. He should consider it in everything he does. Just think of the major changes in a design office and when the Iast one took place in yours, such as simplified drafting. That was nearly 20 years ago. The drawings are to a scale of 1/4, 3/8, 1/2= 1‘- 0”, or some other similar scale. Think of the advance in your shipyard if drawings could be made on a scale of 1/20, with all dimensions in hundredths of an inch, similar to numerically .controlled programs. The foundation of ship design will not crack if the 72” rule is broken. Do not allow designer the right to use the word “equal” when a number of structural members are similar, but require a true dimension. The parts programmers would have a lot less work and the possibility of error would be reduced. Drawing a simple overlay could check most parts by means of the parts programmer with the use of 1/20 scale plots. The designer should not be allowed to inndicate structure unless he defines it in detail. With this type of system, the designer, parts programmer, and fabricator will be as one, The design office will then function as a unit of the shipyard responsible for the complete detail design. In cases where a dimension does not require an exact length, then let it be known, as most yards accept a size as exact. See Figure 3.

It would be easier to make the change to the metric system from this concept because we have utilized the design by inches and decimals of an inch, we now have found the method to convert the detailing process to a computer data base, and this should be the ultimate goal of every shipyard. The straight conversion of a manual design method to a computer base has not, and will not, be easy. The years of designing ships have worn a rut in the brain of the designers’ because he thinks in the concept of total ships: Deck, shells, platforms, bulkhead, bulwarks, superstructure, main longitudinal bulkheads, keel; and the list goes on. Let us try to break this down into groups and subgroups. All ship structure is made-up of plates and shapes. All plates are either flat or curved, all shapes are rolled, extruded, or built-up members. This makes the programming a lot easier if we limit this basic consideration to these few types. Other general observations are that structural shapes are usually cut on the ends except for limbers, vent and drain holes with the exception of transverse members. When work-studying the assembly method this is ideal, as one or two layout men can cut every stiffener on an assemblyThis is very effective because all details are in a standard detailing book, and the details are similar and easy to cut.

The Navy and MARAD have looked at the possibility of a system based on these considerations. The system must have all the basic requirements of an up-to-date production tool for the shipbuilder. It is safe to say the shipbuilders in this country find it hard to develop interest in this approach, as it would require a change that may be too great

to take at once, and the Government, has not offered any special funding to help initiate the Change. Also shipyards are suspect of Government developed systems as they may invoke. controls over the builder. On the Government side, the idea of claims is always present when invoking a Government developed system.

Before we describe a possible computer System, let us first warn the reader of the implementations of a system that puts the responsibility of an entire ship construction,in the hands of a few people. There can be little or no deviation from the way the database is generated as each piece is tied into a control system. This also puts the responsibility of the design squarely on the shoulders of the designer, and his errors could be costly, The checks and balances of a complete system must allow a constant interplay between man and machine. Graphics are a visual aid but computer prinout listings must be checked. To expedite the availability of graphic drawings the shipyard has to be standardized for construction. Eliminate the frills of the past, this includes fancy title blocks, lists of unnecessary references, borders, numerous .unneeded sections of various scales, underlining, extensive notes, and unnecessary signatures of people who do not look at the drawing. All these may be n-ceded under the present system, but with a computer system the information will be in specific reports, and only be highlighted in the graphics.

New high speed plotters can produce deck and shell graphics to any scale required. This gives the design office their graphics, to the scale they wish, and production people will use 1/20 to check their numerically controlled work.

The system must start in the conceptual design phase if we are to develop a complete system. We cannot lose sight of the requirement of good design methods. In the past, the problem of design assisting production was timing and data preparation.

The need for a complete data base in the design area is very criticaI as we cannot check for all problems unless we know how to research them. When we talk of a complete system we should really understand the nature of the system. It need only be complete for the work intended. Also, we must realize that a total system has a great deal of man interface, not the. concept of push the button and out comes your ship.

All computer programs that are used today have one general short-coming, and that is data prepatation. Engineers do not want to draw. Even computer graphics generally turn them off. Designers don't like computer graphics as the first few outputs are poor at best. They feel the manual method would be better. The parts programmer also has highs and lows in his work. He may specialize in an area that does not present a sound challenge. A complete system would help alll individuals and only special parts. would be worked on by various groups.

When a ship is under design development, number of specific areas are working at the same time. Hydrodynamics is developing the hull form, the, Arrangement section is locating the decks and transverse bulkheads, and Stability is checking the stability requirements for the various configurations. The structural engineer is working UP his longitudinal structure requirements. With the present day manual method, these are all independent actions. The database approach allows for a complete change.

The hydrodynamicist is developing a set of lines in the computer. This could be no more than the first or second input of basic control lines, He could at that time estimate the height, sheer, and camber of the weather deck. Each control line is assigned an identifier. The arrangement and structural sections can take these preliminary lines and start their own process. By keying into the original identifier, the three sections use fines that move as one, when the lines shift during development. The hydrodyamicist may call a specific we a waterline, and the arrangement and structured system would call that waterline an internal deck line. A buttock line may be a longitudinal bulkhead.

As stated, most people do not like to prepare data for only one purpose. In this regard the structural engineer enjoys structural design but no other discipline cares if he spends an hour, a day, a week, or month, on a specific area. Other disciplines are only interested in its impact on their area. The use of the structural design tool to assist in graphic output could be the salvation of a sound integrated system. Let us assume that we have the body Plan Of a typical ship, and a computer program to develop a midship or other longitudinal structure at various sections of **a** ship. The Navy has such a system called Structural Synthesis Design Program (SSDP). This system allows the engineer to input the location of major longitudinal surfaces such as shell, decks, longitudinal bulkheads and loading conditions, along with average longitudinal stiffener spacing, and the system will define. the necessary plating thickness and Longitudinal structure based on the loads and geometry input. By interfacing this with a computer drafting Program the engineer can establish data points for various surfaces wihout major data preparation. Manual interface is required to string these various sections, together via a structural body plan and shell expansion. For this the engineer will be specific in his locations and drop off of various members. He now fits this data back into SSDP and doubles the number of sections. This allows a design tool to direct a drafting tool, SSDP output is fed into two files, a line file that defines the location of the structure and a scantling file to give the thickness or size for both plates and shapes. MARAD is presently considering the further development of SSDP to include ships designed to American Bureau of Ships Standards.

With the use of identifiers in lieu of specific locations we are allowing the various components of the system the flexibility to develop their specific expertise and still interface with the originator of the data point. This technique is most important to all disciplines of ship design development and construction, with the cognizant department, code/section having the proper responsibility.

We have deviated so much from past practice, let us recap a little. The Hydrodynamic group is responsible for the hull development and appendages to the shell, the Arrangement section is responsible for location of all decks, platforms, flats and levels and in conjunction with Stability are responsible for all major structural bulkheads. The Arrangement section is also responsible for the location of all major and minor openings and miscellaneous structure and joiner work. The Structural section is responsible for all major and minor structure, including girders, longitudinals, stanchions, and transverse members. With the various discipline defined, we see that everyone can extract information from the cognizant code while inputting their own information.

We will limit further discussion to just structures. The responsibility of the structural engineer is to design for both primary and secondary loading conditions and to provide a structural arrangement that is compatible with the needs of the overall ship operation.

The structural engineer continues to tune the design and the other sections use his output by going to a cross index file to look up information they may wish to extract. Arrangements may call for all stanchions, and they will be shown as pipe or shapes at specific locations. The location of web frames, stanchions, and girders is important to various departments for their specific needs.

The structural engineer will periodically call up a simple graphic plot of all openings to check for locations. In the early design phase, when openings move often, indication of openings with the area still plated in will save a great deal of time.

When the design manager calls for a drawing review, or circulation, the various sections would not be affected. The data base would reflect the latest thinking, and graphic outputs could be extracted for the various drawings in a timely fashion. Compared to today's method, where each section loses use of the. tracing for an extended period of

time, this would not be the case in a controlled system. The design manager would have a setup supplied by the various sections that would allow him to extract the needed data for his drawings to meet circulation dates.

We can now assume that the ship has gone through feasibility, conceptual, preliminary and contract design stages. The qualified shipbuilders are brought on board to familiarze them as to the special features of the design, and also to learn the details of structure available in the data base.

The result of this effort is a set of contract and contract guidance drawings. More important, it is a complete data base of all major structure; and a bill of material by plate thickness, square foot area, stiffener size and total length. A close survey of ships designed by the Navy has indicated that 85% of the plates and shapes indicated on the contract and contract guidance drawings, are actually used for construction of the ship,

When the system is first being used it will require a training period for the varvious skip design offices. The use of an identifier to replace the historical ship terms may ,seem difficult at first, but should be easily understood, as the identifiers are usually functional abbreviations of the various components. Examples - SH (Shell), DK (Deck), PF (platform), WI(waterline), PL (Plate), PC (Piece), ST (Stiffener), WF (Web Frame).

The output from the data base is the standard deck, shell, and bulkhead drawings, with some expansion. The deck drawings will include both port and starboard. The shell drawing will indicate both port and starboard shells and can both face the same way with hidden lines for members on the starboard and solid lines on the port view. The transverse bulkheads drawing will cover all bulkheads. The web frames and possibly some of the transverse bulkheads could be produced on a printer to reduce plot time. A complete bill of material will be available. The contractor will introduce master butts and have a preliminary cut at assemblies. The bill of material would be rerun and divided by assemblies. Care should be taken to insure that this division will be close to an acceptable erection approach, as the responsibility is changing hands from the contract design phase to the working drawing phase.

When the shipbuilder has accepted the contract package, the data base will be copied and provided for his design office. In general, the detail design is basically a process of expanding or detailing specific parts with a limited amount of original engineering. Most Navy contracts have all the design criteria in the detail specifications but most yards spot check the original contract design and concentrate on the areas not covered, such as main machinery, foundations and general foundations. Miscellaneous bulkheads are usually copies of adjoining structural bulkheads and trunks.

The design office can now assist the construction people in the definition of the ship by simply suppressing the sizes of various members. They will also supply complete layouts of various assemblies, not only by surfaces, but with isometric views for easier interpretation. The first setup will take a litte time and could be accomplished during negotiations. The following efforts would only require a reshuffle of data. This is the first step in design assisting construction with many more to follow.

At this time, the hull is finalized into asemblies and each assembly leader in design has his own data base. The steps from this point on are very similar to the assembly approach described in the manual method, with a few' exceptions. Progress can be measured based on the number of computer runs that are made. This really gives management a tool to work with as the costs are easy to assess and the progress can be measured. It is a very competitive way to work with teams trying to complete their assembly and most employees taking on a new interest. Once a team is established, their weakness and strength can be realized quickly and added training will correct the weakness. If for some reason a major change is made such as a modification to the combat suit, the ease of controlling a change can be readily realized.

The various assemblies could easily be merged together and produce the old reliable as-built drawings without much difficulty. The suppression and proper orientation of the various surfaces in a file, plotted out with a new up-dated data base, would give the owner of the ship a complete file of drawings for his ship. If the follow ships were awarded to another shipbuilder he could decide if the existing design would suit his special needs and the lead builder would not be responsible for the changes. This allows everyone to do their own thing and should give the owners duplication of ships.

The first thing a team leader should do is locate all major openings, or fixed openings, and introduce the necessary butts and seams for any known insert plate or changes in plate thickness. This could supply them a plate bill of material. The bill of material will be in several forms, for different reasons this is unlike the manual method. one by surface in an assembly, such as, all the plates on a deck. A separate listing by plate thickness and a comparison document could be a series of graphics of the pieces, in bounding rectangles to reduce waste. This is important to allow for close ordering of material and establish the preliminary nesting for numerically controlled burning. The nesting process starts before the material is ordered. With the use of local coordinates the nesting method is established for major plates. Only the remainder of the ordered plate is still available for small or miscellaneous pieces not yet defined.

In small yards, or yards with limited material handling or crane capabilities, it may be better to order by assemblies so several ship sets can be ordered as they are to be used. Management has a tool to evaluate the problems associated with volume ordering based on construction needs,

The next step is upgrading the numerous scantlings on the various surfaces of the assembly. This includes extruded, rolled, built-up members, plate beams and stanchions. me method of input into the database is defined as stiffener members including both sizes of a ship. This is similar to the standard numbering of longitudinals on the deck from the centerline out, and on the shell from the keel up, both port and starboard. The size is given, and the members scantling size must be in the library of shapes available, with the overall length checked by the designer. The identifier is given as a surface identification. The distance from the forward perpendicular for the start and finish of each piece also lists all surfaces that are penetrated. The system will take it from there and make all necessary cutouts, order necessary collar plates, chocks, lugs or other minor structure. The system will locate a butt or seam that crosses the member and introduces a limber opening. A major problem in a computer system is a molded surface and the necessary modifications to a plate or shape that has a thickness of material on the other side of an abutting structure. What type of output should be available from this data?

The review of a structural working drawing takes time. The amount of study that presently goes on in a shipyard is unaccountable because no one admit to the time it took to clarify just what the designer intended. In many cases, the worker may not be able to read a typical blueprint. When we consider a computer system, blueprint reading is not necessary.

With the central data base the job is so much easier. Let us think of the various steps and consider what would be of help. In cutting plate pieces, all pieces that are true rectangles should be known and the number of each specific size noted. This could be listed and will then constitute a family of parts. If the ship builder has a heavy duty shear, he could elect to cut them this way and let the transverse frames and bulkheads locate the longitudinal stiffener on the structure, if edge proporation for welding was not a requirement.

The use of simple assembly graphic drawings is to show the cross association of plate pieces and their identifiers with the weld sequence required. This type of graphic is presently not in use in shipyards today. To these simple graphics, the welding engineer could indicate the weld sequences. In many yards today, the proper weld sequence is

poorly defined and a lot of cutting and refit work is done. The-reason is that a weld sequence drawing is high in cost and time consuming, and the amount of rework repair is unknown and most yards would like to think it is worth the chance. Poor planning is nearly as good as no planning.

The possibility of supplying-graphic drawings of each surface in the same view or plane as the surface which is being constructed would make the shipfitters fabrication easier. When various surfaces are joined, only simple graphics are required to detail connection points. The use of one complex drawing to cover the entire ship is poor at best. The increase in paper may be a concern but in many cases the individual drawing could be produced on a printer or small scale graphic plotter with a detail listing of the parts, the amount of various welds, the type of electrode. Now, instead of a piece number for each piece, the surface is the piece identifier. Controlled planning would allow for shipping, handling, and schedule requirements including inspection.

The butt welders don't care about the fillet welding and the other parameters necessary for other trades, so there is no need to tell him. For the yards that have panel welds, the program could search for the number of similar plate and stiffener pieces and a setup would be made. Even the different lengths could be part of the family of parts.

A study of the yard should be made to see if the openings should be left attached, with a bridge, to improve production by reducing special cases in construction. The hole would already be cut, the yard could wait till later to open up the piece. Distortion would be reduced, thereby, getting more use from the panel welder. In aluminum constrution this would have a lot of merit.

The study of how to handle stiffeners is a very important subject. The first listing to be printed is the stiffener bill of material (BOM). At the present time, the plate or built-up members will be covered in the plate bill of material, and a supplemental plate BOM is required to pick Up these pieces. The stiffener bill of material could have a standard format be adjusted, as required, by a shipbuilder and even print out his indicated sizes under **his** letterhead. The stiffener BOM will come in stiffener pieces identified by surface in an assembly. See Figure 4.

Summary: B/M similar to the plate BOM. The other report is by various stiffeners. Stiffeners are available in orderable lengths of 20,30, and 40 feet. The program reviews the number of lengths to cut the right number of pieces, and gives the number of pieces, the percentage of waste by lengths, and also by total of lengths. See Figure 5.

A review of the previous figures show that the System works on a six character identifier, with all Unnecessary zeros suppressed, that makes for easy readirig. If a directory of identifiers and equivalent ship terms is available on the graphic drawing or a small notebook for everyone to carry around, it would make it easier for most production people.

The cost of any computer program is commensurate with the data processed. To reduce cost a system of mirror images should be available and along with adjustments in programs, port and starboard identifiers can be produced. For cargo or tanker ships this is fine, but for combatants, it may be a waste of time.

Up to this point, we have defined the hull form, the plated areas, the shell, decks and bulkheads, and the extent of both longitudinal and transverse shapes that cross the major hull surfaces. We have been able to order the plate pieces and stiffeners. Also by this time, most numerical control tapes could be generated. **This** is different than the part programming method, as the numerically controlled graphics are produced from the data base before the tapes are generated. A listing of each tape is available and this is done by use of a post processor for a specific

type of numerically controlled equipment. A review of the graphics on individual pieces is made and the bill of material graphics for nested plates is checked. The location of bridges between pieces is picked. Those pieces involved are set out in a file, the necessary bridges made then stored in the data base.

The system should take each numerically controlled tape listing and run it through an optimization program that reduces the dead travel time and produces anew graphic. It indicates the piece ID, all punch marking and burning and also notes the amount of fast and slow travel in inches. This will allow for better scheduling of numerically controlled burning time. By adding the amounts against the thickness of the plate to be burned, management can determine if a specific task can be done by one shift with some overtime, or if two shifts will be required. This could be programmed to print out that information as a management tool. When numerically controlled burning has reached complete acceptance, the possibility of having numerically controlled machines at steel mills, and only shipping finished plates with punched ID's, could really save money. This may be a reality if pursued. Also, if a plate requires rolling, it could be noted and scheduled first as this would help the critical path.

The majority of computer systems are developed to cut plates using numerically controlled tapes that also punch mark the location of structural members. Definition of the structural member is done in the steel fabrication area or laid out in a loft or shop planning office and in most cases by hand.

A review was made on a LNG Carrier of 22,600 Long Tons, (LT) and a Barge Carrier of 14,000 LT. Figures list the quantities of various details and the hours required for layout, loft, cut or burn, fitup, installation, welding, inspections and handling for details. This requires a significant percentage of all hull steel fabrication and erection cost. If the actual percent of shipbuilding hours were available the amount would be quite high. See Figure 6.

We have talked about various aspects of a system and now we must talk about structural details. The concern of structural details should be considered as the heart of structural design. Poor detail at a critical location has, in most cases, been the primary source of structural failure. Without proper attention in the design office, poor details can creep into a design without the knowledge of responsible parties. This can happen from lack of specific detailing for each intersection point or assembly. The responsibly of detailing may fall on the shipfitter level if the design office has not assumed the proper responsibility. A notch, rough cut, misalignment, poor welding or undefined erection sequence may cause a failure. A good QA program in support of a good design can protect the ship against the design problem by incorporation of standard details. A detail is the joint or point on a surface where an "event" occurs. The events can include a member ending on another structure, or a member penetrating a deeper member. The variations of these samples are many. With the addition of brackets, chhocks and collar plates, the detail becomes complex. The system should have a method of inspecting the detail point by cross association of members and plate surfaces. This is the expensive part of construction and of a computer system, because many checks must be made, From this cross association of plate surfaces and number pieces the following information is available, first, from an assembly point of view, then from a detail point.

1) The end cuts of members are defined.

2) The location of, and quantity of, minor structure is available; a chocks, brackets, lugs, sole plates and collars, and also the type of watertight nontight, flush or lapped collars. This gives the planner a very good tool as he finally has a count of each type of part within an assembly, and in some cases, he may find only one of a given size and shape, then hundreds of another. The miscellaneous minor structure can be cut from the surplus from nested plates or because the number may be cut from large specially ordered plates. Also, another review can be made of special thicknesses, which could be rounded off to available material, when a slight weight increase is acceptable.

The library of details is very importants. Using the surface identifier, the system can control the use of a detail. If a specific configuration is not in the library, the system will print a note indicating that the detail is not implemented. This gives the designer a chance to review the structural configuration and decide if a change in associated structure or implementation of the detail is necessary. This is extremely important in ships that are weight critical, especially in aluminum hulls, as steel detail is not always acceptable for aluminum construction. Much more care is required at detail points, and transition pieces are criticaI. When working with alnminum, the builder finds the material is less forgiving than steel.

We have taken the information and developed a stiffener fabrication report that tells just how to cut the stiffener not only at the ends but along the web of the member. The location of the minor structure that is required and also a bending template if required. This data could be programmed to fit bending machine, when available.

We have a way of cutting each stiffener in an assembly. It is a good move, but we now need to develop a system of mass production. An evaluation earlier noted that the majority of members are cut only on the end. This allows the system to check the data base and sort alI similar size members with identifiable end cuts, even though the length varies, and to group them in order of length. See Figure 7. This is a good use of group technology as We are deveIopoing a fmily of parts. We also may have some stiffeners with additionrd cuts and bending required. The system identifies the page of the report which describes specific interior cuts or bending. This is the step that superceded the capability to check the random lengths of the bill of materials based on orderable lengths. The program could be run and the material waste calculated in a production mode. With this summary listing, the system could produce a series of labels in the same order as the stiffeners are cut. This would identify the member with ease. For aluminum hulls, this system is ideal. In steel hulls, the procedure is good only if the material is not left loose or exposed to the weather for a long period of time.

Capabilities that could be made available is a report of the length of weld to specifically note the amount of each type or size of weld by piece, surface or assembly. This would assist in establishing critical path and manpower requirements.

In conclusion, it must be noted that any design office can make a serious inroad into the production method of their shipyard, and still prepare designs with the same amount of manhours or less. If and when a yard is ready to introduce computer generated data for construction in a serious, way, management must realize that the designer will be the single source of information.

Management will realize a sizable reduction in the number of people in design costs, weight control costs, mold loft costs, and planning. The disadvantage is the power a system like this will leave in the hands of a few. Sound shipbuilding people are getting harder to find.

In a limited market the good will rise and if the money is not right, will move. If only shipbuilding was like sex and could be learned over night! A serious problem in todays shipyards is who should receive what drawings, scheduling, planning documents and general pieces of paper. In the computer system the documents would be developed for a certain need and limit the number of people that would receive the information.

Production people will accept the change much more readily than the design office. The design office will find problems as the computer has no judgement factor that will correct misinformation. The change will be made at some time especially if other countries try and have success.

Just let your mind run and realize that the proposed system is nearly avaiIable. The follow-on from this is a similar approach to develop the following:

1. Joiner bulkheads with all associated pieces listed and defined.

2. Door, hatch and scuttle lists.

3. Key lists.

4. Insulation drawings and material lists.

5. Paint schedule and material ordering list based on thickness and square footage.

6. Deck covering schedule.

7. And from your own experience you could add many more.

The cost of material and labor demands a central system as the manual method is costly. The scheduling of unknowns based on poor guesses is one of the main reasons for poor shipyard schedules.

Using the assembly approach, the amount of welding wire, staging, and amount of outfitting will be better controlled. Present day unknowns will have more traceability and everyone will have a better handle on their part of the job.

The assembly approach would allow for a more accurate method of progress payments. The cash flow problem will be better than controlled. In times of need, high cost assemblies could be fabricated and assist in getting the buiIder the money required to meet cash flow problems.

REFERENCES

1. R. Glasfeld, D. Jordan and D. Zoller, "Review of Structural Details." Ship Structure Committee Publication SSC 266.1977.

2. C. C. Gallagher, S. K. Banerjee and G. Southern, "Group Technology in the Shipbuilding Industry." Taylor & Francis, Ltd., London. 1973.

3. M. Aughey, "Unii3ed Hull Definition System." IIT Research Institute, Chicago. 1975.

4. P.M. Palermo, "An Overview of Structural Integrity Technology." The Society of Naval Architects and Marine Engineers, New York. 1975.

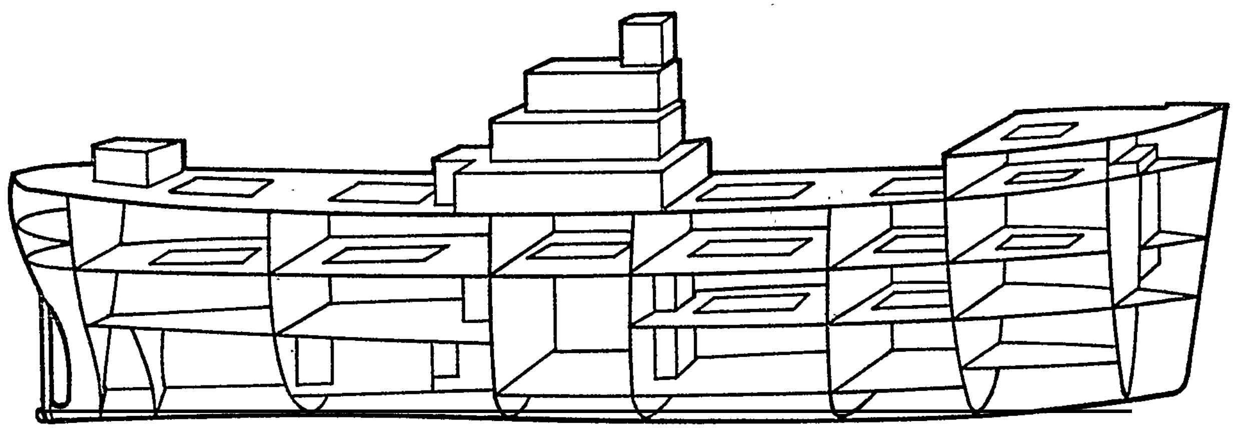

FIGURE 1

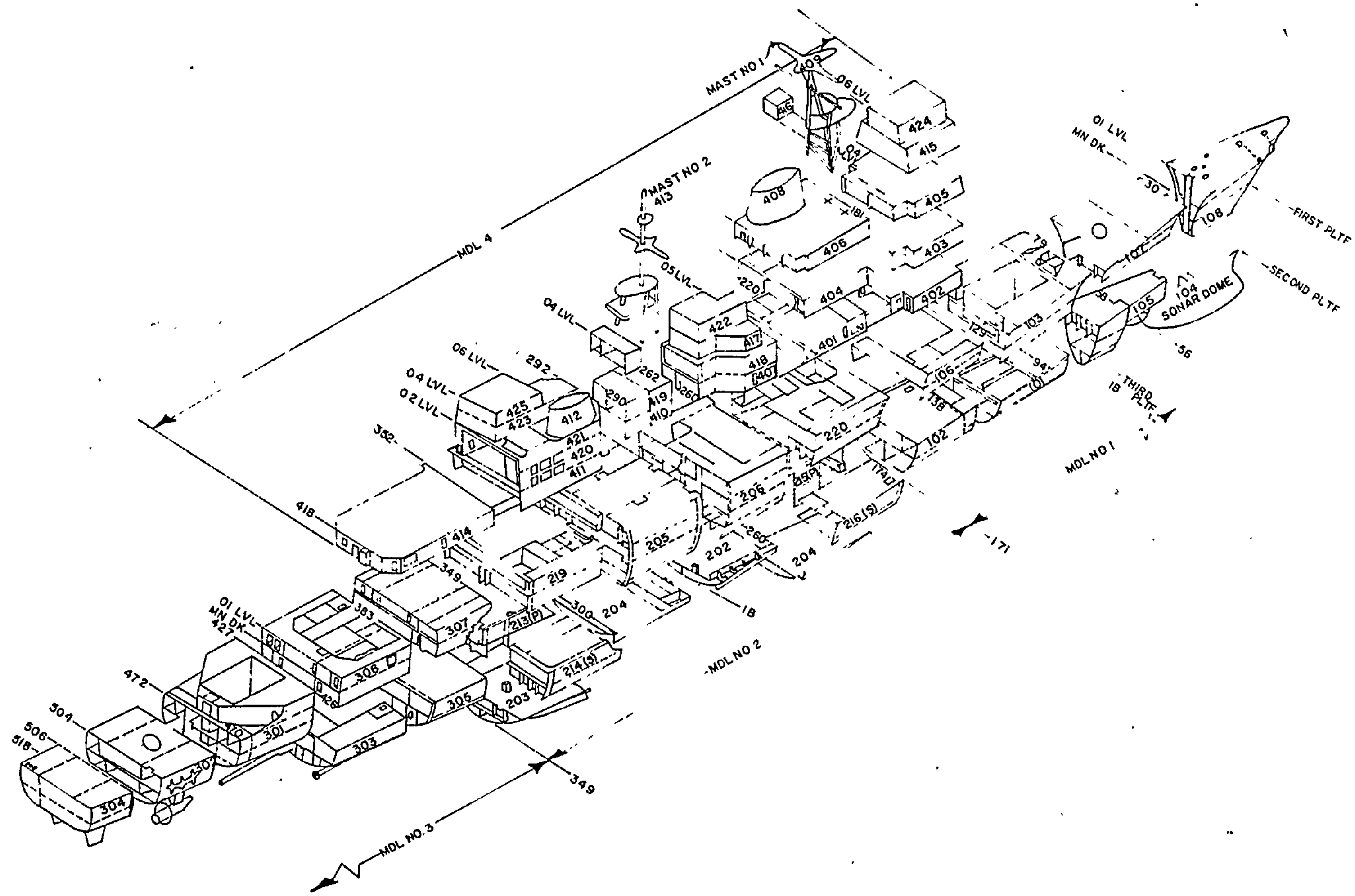
MAST NO 1
06 LVL
424
415
405
403
402
401
404
406
408
MAST NO 2
413
05 LVL
04 LVL
06 LVL
04 LVL
02 LVL
292
425
423
412
422
417
418
407
262
290
419
410
260
421
420
411
220
206
205
202
204
219
213(P)
214(S)
216(S)
01 LVL
MN DK
30
108
107
104
105
SONAR DOME
FIRST PLTF
SECOND PLTF
THIRD PLTF
18
56
103
106
102
MDL NO 1
MDL 4
MDL NO 2
MDL NO. 3
171
349
18
418
414
349
307
308
305
303
301
203
472
504
506
518
304
383
427
426

FIGURE 2

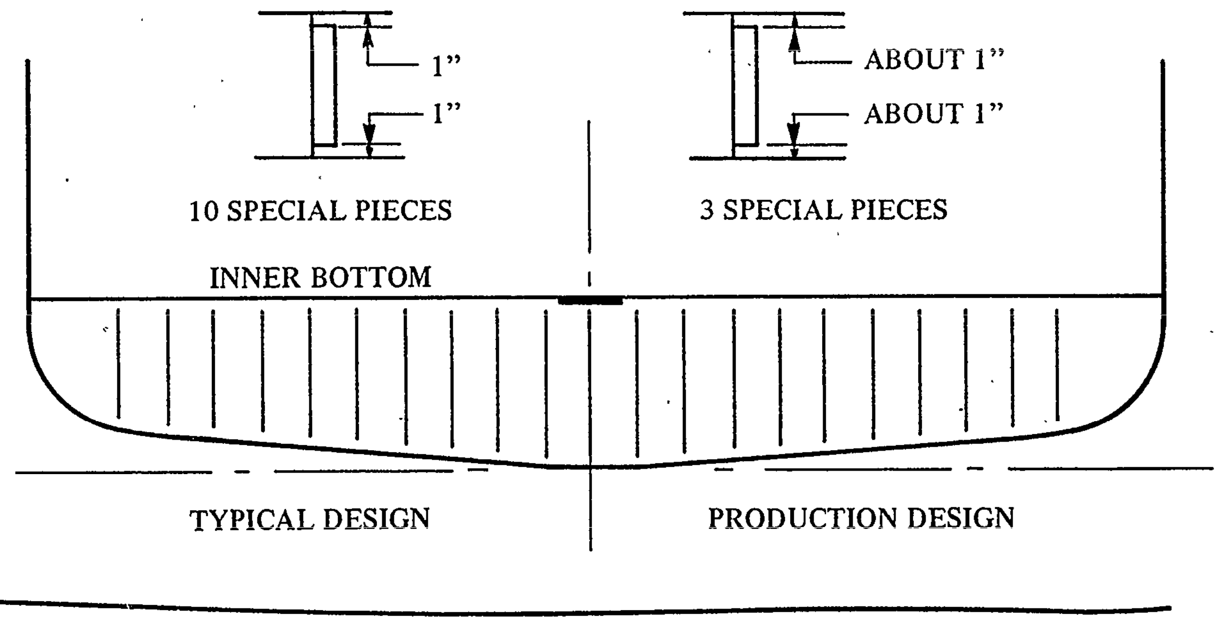
1"
1"
10 SPECIAL PIECES
ABOUT 1"
ABOUT 1"
3 SPECIAL PIECES
INNER BOTTOM
TYPICAL DESIGN
PRODUCTION DESIGN

FIGURE 3

SURFACE	STIFFENER ID	SCANTLINGS	METAL	LENGTH	WEIGHT (LBS)
SHS	WF0750 PCO012	10 X53/4X25.001-T	MS	6-02-02	106.30
SHS	GRSOOO PCOO03	14X8X48.001-T "	MS	5-09-07	190.86
sHS	STSO1O PCOOO1	4X4X5.00T	**MS**	23-10-11	120.23
SHS	STS020 PCOO02	4X4X5.00T	MS	Z3-IQ-06	120.10
SHS	STS040 PCOO04	4X4X5.00T	MS	15-03-04	76.85
SHS	STS050 PCOO05	4X4X5.00T	MS	15-02-03	76.40
SHS	STS060 PCOO07	4X4X5.00T	MS	15-06-02	78.05
SHS	STS060 PCOO08	4X4X5.00T	**MS**	3-07-02	18.09
SHS	STS080 PCOO09	4X4X5.00T	MS	5-03-03	26.50
SHS	STS11O PCOO1O	4X4X5.00T .	MS	24-06-05	123.43
SHS	STSIZO PCOO1I	4X4X5.00T	MS	24.06-01	123.32
SHS	STS070 PCOO08	4X4X5.00T	MS	15.00-13	75.82

I *STIFFENER WEIGHT FOR THIS SURFACE –1135.96LBS

TB665	PST025	4X4X5.00T	MS	60O-10	30.46
T8665	PST026	4X4X5.00T	MS	6-06-10	32.98
TB665	PST027	4X4X5.00T	MS	6-10.04	34.48
TB665	PST028	4X4X5.00T	MS	6-11.06	34.96
TB665	PST029	4X4X5.00T	MS	7-03-09	36.72
TB665	PST030	4X4X5.00T	MS	7-03-10	36.76
T8665	PST031	4X4X5.00T	MS	7-03-10	36.76-
TB665	PST032	4X4X5.00T	MS	7-03-09	36.72
TB665	PST033	4X4X5.00T	MS	3-06-10	17.87
TB665	PST034	4X4X5.00T	MS	4-03-00	21.40
TB665	PST035	4X4X5.00T	**MS**	3-05-06	17.34
TB665	PST036	4X4X5.00T	MS	6-10-04	34.48
T8665	PST037	4X4X5.00T	MS	6-06-10	32.98
TB665	PST038	4X4X5.00T	MS,	6-00-10	30.46.

****STIFFENER WEIGHT FOR THIS SURFACE – 434.35 LBS**

****TOTAL STIFFENER WEIGHT FOR THIS ASSEMBLY –4423.29 LBS**

STIFFENER BILL OF MATERIAL BY SURFACE

SURFACE ISALPHABETICAL
STIFFENER LENGTH SHQWN IN FT-IN-16THS

SHIP-
ASSY- SA5
10/22/ PAGE: 2

FIGURE 4

QUANTITY	SCANTLINGS	LENGTH	SURFACE	STIFFENER I.D.	LENGTHS IN FT 20	30	40	PERCENT OF WASTE 20	30	40
1	4X4X5.00T	3-05-06	TB665	PST035	*	*	*	*	*	*
1	4X4X5.00T	3-06-10	TB665	PST033	*	*	*	*	*	*
1	4X4X5.00T	3-07-02	SHS	STS060 P08	*	*	*	*	*	*
1	4X4X5.00T	4-03-00	TB665	PST034	*	*	*	*	*	*
1	4X4X5.00T	4-09-13	LBST35	PST006	1	*	*	1.7	*	*
1	4X4X5.00T	5-03-03	SHS	STS080 P09	*	1	*	*	16.9	*
2	4X4X5.00T	6-00-10	TB665	PST025	*	*	*	*	*	*
	4X4X5.00T	6-00-10	TB665	PST038	1	*	1	13.1	*	7.4
2	4X4X5.00T	6-06-10	TB665	PST026	*	*	*	*	*	*
	4X4X5.00T	6-06-10	TB665	PST037	*	1	*	*	16.0	*
1	4X4X5.00T	6-08-02	LBST3S	PST007	1	*	*	1.1	*	*
2	4X4X5.00T	6-10-04	TB665	PST027	*	*	*	*	*	*
	4X4X5.00T	6-10-04	TB665	PST036	1	*	1	31.5	*	16.3
1	4X4X5.00T	6-11-06	TB665	PST028	*	1	*	*	8.9	*
1	4X4X5.00T	7-00-02	LBST3S	PSL008	1	*	*	30.2	*	*
1	4X4X5.00T	7-02-14	LBST3S	PSL009	*	*	*	*	*	*
2	4X4X5.00T	7-03-09	TB665	PST029	1	*	*	27.3	*	*
	4X4X5.00T	7-03-09	TB665	PST032	*	1	1	*	3.8	10.5
2	4X4X5.00T	7-03-10	TB665	PST030	1	*	*	27.0	*	*
	4X4X5.00T	7-03-10	TB665	PST031	*	*	*	*	*	*
1	4X4X5.00T	7-05-08	LBST3S	PSL010	1	1	*	26.2	26.4	*
1	4X4X5.00T	15-00-13	SHS	STS070 P06	1	1	1	24.7	49.8	7.2
1	4X4X5.00T	15-02--3	SHS	STS050 P05	1	1	*	24.1	49.4	*
1	4X4X5.00T	15-03-04	SHS	STS040 P04	1	1	1	23.6	49.1	23.9
1	4X4X5.00T	15-06-02	SHS	STS060 P07	1	1	*	22.4	48.3	*
1	4X4X5.00T	23-10-06	SHS	STS020 P02	NA	1	1	NA	20.4	1.6
1	4X4X5.00T	23-10-11	SHS	STS010 P01	NA	1	1	NA	20.4	40.3
1	4X4X5.00T	24-06-01	SHS	STS120 P011	NA	1	1	NA	18.3	38.7
1	4X4X5.00T	24-06-05	SHS	STS110 P010	NA	1	1	NA	18.2	38.7

LENGTH X NO. OF PIECES X WEIGHT = TOTAL WEIGHT					TOTAL CUT LENGTH	TOTAL PERCENT WASTE
20 FT	X	NA	X 5.032	= NA	NA	NA
30 FT	X	13	X 5.032	= 1952.480	286.215 FT	26.5
40 FT	X	9	X 5.032	= 1811.520	286.215 FT	20.5

STIFFENER BILL OF MATERIAL
SUMMARY REPORT

*STIFFENER LENGTH SHOWN IN FT-IN-16THS
METAL TYPE — MS

SHIP-
ASSY-SA5
10/22/7 PAGE: 3

FIGURE 5

COUNT AND RANKING OF SHIP STRUCTURAL DETAILS

LNG CARRIER

RANK	TYPE – DESCRIPTION	TOTAL COUNT	TOTAL MANHOURS
1	Panel Stiffeners	11090	51835
2	Brackets	1330	14760
3	Scallops	20020	10605
4	Openings in Girders	12700	10510
5	Structural Intersections	4950	8640
6	Chocks	1180	5080
7	Tripping Brackets .	740	2530
8	Stanchion Support	190	2000
9	Stiffener Endings	1360	1180
10	Snipes	770	230
11	Mkcellaneous Cutouts	150	**7 0**

Total 170,440

BARGE CARRIER

1	Structural Intersection	22880	62910
2	Stiffener Endings – Chocks	11590	27125
3	Panel Stiffeners	7050	26455
4	Brackets	1200	4550
5	Tripping Brackets	250	3333
6	Openings in Girders	7370	3270
7	Stanchion Support	390	2700
8	Snipes	500	140
9	scallops	.200	90

Total 130,573

FIGURE 6

SUMMARY OF END CUTS

```
*********...********          *********...********
*                  *          *                  *
*                  *          *                  *
*                  *          *  ****  ...  **** *
*                  *          *                  *
*********...********          *                  *
*********...********          *********...********
```

ENDOO1 TYPE 7-01

NO CUTS

END002 TYPE 7-01

NO CUTS

***SCANTLINGS - 4x4x5.00T

STIFFENERS WITH ABOVE END CUTS

PAGE	QTY	LENGTH	SURFACE	STIFFENER
176	5	6-11-13	LBST7P	PSL029
174		6-11-13	LBST7P	PSL028
168		6-11-13	LBST6S	PSL042
166		6-11-13	LBST6S	PSL041
164		6-11-13	L8ST6S	PSL040
144	5	6-11-12	LBST4S	PSL015
142		6.11-12	LBST4S	PSL014
140		'6-11-12	L8ST4S	P5LO13
130		6-1 1~12	LBST4P	PSLO09
128		6-11-12	L8ST4P	PSLO08
126		6-11-12	LBST4F	PSLO07

SUMMARY OF END CUTS
FOR ASSEMBLY – SAOO3 METAL TYPE – MS

FIGURE 7

SUMMARY OF END CUTS

```
S*******...*** C * S
*                  *
*                  *
*                  *
*            .     *
*********...********
*********...********
```

E00683 TYPE 8-01

NO CUTS

```
*********...********
*                  *
*                  *
*  ****  ...  **** *
*                  *
*                  *
*********...********
```

E00893 TYPE 8-01

NO CUTS

STIFFENERS WITH ABOVE END CUTS ****SCANTLINGS - 4X4X5.00T ****

PAGE	QTY	LENGTH	SURFACE	STIFFENER I.D.		
259	8	21-00-00	SH000S	STS100 P00009		*OTHER CUTS REQUIRED
265		21-00-00	SH000S	STS120 P00011		*OTHER CUTS REQUIRED
262		21-00-00	SH000S	STS110 P00010		*OTHER CUTS REQUIRED
246		21-00-00	SH000S	STS060 P00005	*BENDING REQUIRED	*OTHER CUTS REQUIRED
243		21-00-00	SH000S	STS050 P00004	*BENDING REQUIRED	*OTHER CUTS REQUIRED
240		21-00-00	SH000S	STS040 P00003	*BENDING REQUIRED	*OTHER CUTS REQUIRED
237		21-00-00	SH000S	STS020 P00002	*BENDING REQUIRED	*OTHER CUTS REQUIRED
234		21-00-00	SH000S	STS010 P00001	*BENDING REQUIRED	*OTHER CUTS REQUIRED

SUMMARY OF END CUTS
FOR ASSEMBLY – SA0003 METAL TYPE – MS

DATE:
PAGE: 382

FIGURE 8

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